THE TILLAGE MACHINERY LABORATORY

of the United States Department of Agriculture

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U.S. DEPARTMENT OF AGRICULTURE

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Most of the tillage implements and transport and traction equipment now in use on the farm have been developed on the basis of field experience, without regard to the scientific relationship between soil characteristics and equipment design. As a result, tillage and other field operations frequently use an excessive amount of power and are not as effective as they should be.

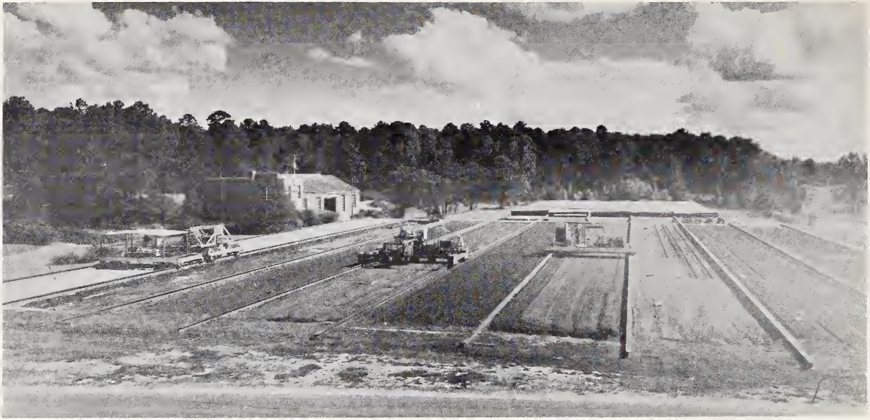
Also tillage and other field operations have a cumulative effect on soil conditions that affect crop response. They may result in excessive compaction or other damage to the physical character of certain soils.

The United States Department of Agriculture Tillage Machinery Laboratory is directly concerned with these problems. Research at the laboratory is furnishing information that will aid in more efficient use of the existing equipment and give a basis for the design of new and improved equipment.

THE LABORATORY: HISTORY AND PURPOSE

The Tillage Machinery Laboratory is a part of the Agricultural Engineering Research Division of the Agricultural Research Service. It is located at Auburn, Ala., on a site furnished to the Federal Government by the Alabama Agricultural Experiment Station under a 99-year lease.

The laboratory was established in 1935. It was set up originally to undertake research relating to the tillage practices and machinery used in cotton production. (This was a major factor in selecting a location.) However, since



The Tillage Machinery Laboratory at Auburn, Ala.

many of the problems in cotton production were common to other crops, the scope of the research was broadened to include all tillage practices and machinery.

Setting up the laboratory eliminated many of the difficulties that had been encountered previously in tillage research. For example, studies had to be made in the field and at different locations in order to work with a variety of soil types. The studies were often delayed until natural forces produced the desired soil condition in the test field. It was difficult to obtain comprehensive data in the studies because in field work there are many variables that affect the condition of the soil.

At the laboratory, test equipment, trained personnel, and a wide range of soil types have been concentrated at one point. Full-size tillage, transport, and traction equipment can be tested under controlled soil conditions and equipment operation. Different soil conditions can be produced in the test soils at the laboratory and can be duplicated when necessary.

THE WORK AT THE LABORATORY

The Research Program

The research program at the laboratory is composed of projects covering tillage, transport, and traction. Studies are made to determine--

(1) The performance characteristics and draft requirements of tillage implements.

(2) The efficiency of traction equipment.

(3) The effect, under different soil situations, of tillage, transport, and traction operations on soil conditions.

Tillage implements and transport and traction equipment are tested in different soils and under various moisture and density conditions of the soils. From these tests, basic information is obtained concerning--

- The physical effects produced upon the soil by different methods of tillage.
- The minimum amount of soil manipulation necessary to produce the desired tilth.
- The power requirements of different types of tillage equipment.
- The effects of variation in design, in working depth, and in speed of operation on the power requirements.
- The directional components of the draft for different designs and adjustments of tillage implements.
- The effects of soil-type characteristics and of the physical condition of the soil on the power requirements and upon the amount of soil manipulation necessary to produce the desired tilth.
- The relation of different plow designs to the draft requirement and to the effect upon furrow slice of throw, inversion, pulverization, and coverage at different speeds and depths of plowing.
- The effects on the soil of the wheels and tracks of transport and traction equipment.

The program includes also field studies for the practical evaluation of data obtained in the work at the laboratory. Arrangements have been made with State agricultural experiment stations for use of their facilities in the field work. The stations also cooperate in the research work.

Cooperative Work

In its research work, the laboratory cooperates with and assists other agencies interested in tillage or otherwise concerned with the soil.

There is both formal and informal cooperation with other research agencies of the Department of Agriculture as the need and opportunities arise. For some time, there has been a cooperative research program with the Soil and Water Conservation Research Division of the Agricultural Research Service. The program is concerned principally with the effects of field equipment on soil characteristics that affect crop response.

During World War II, the laboratory's work was devoted entirely to the defense effort. Cooperative studies were made with the Armed Services in solving problems of transport and traction over soils. Similar cooperative studies are still under way.

Cooperation and assistance are also extended to private industry concerned with the development and improvement of tillage and traction equipment. Representatives from interested agencies frequently visit the laboratory to observe the work or join with the staff in field tests conducted as part of the research program.

The facilities and personnel at the laboratory are available to equipment manufacturers for testing their equipment in the productive or experimental stage. Cooperative studies have been made with manufacturers of such equipment as plows, rotary tillers, colters, sub-soilers, disk-harrow blades, cultivator sweeps, corn and cotton planters, traction tires, and tractor tracks. In many of these studies, fundamental data are obtained that are

included in technical papers published in professional journals. In practically all the studies, the cooperating companies obtain data that enable them to serve the farmer better.

Cooperation with private industry is limited to the development of basic information that is useful over extensive areas and beneficial to the entire industry concerned.

THE TESTING FACILITIES AND EQUIPMENT

The Soil Bins

The laboratory maintains nine soil bins, or plots, which contain surface soils selected for making tests. Each bin is 250 feet long and 20 feet wide and is designed to hold a 2-foot depth of surface soil. The bins are separated by concrete walls, and a concrete apron is provided at the end of each bin for assembling test equipment.

A steel rail is mounted on the top of each separating wall. Specially designed cars, or carriages, used in testing tillage implements or other equipment, run on these rails. During a test, only the tillage tool, or wheel or track of the transport or traction equipment, comes in contact with the soil.

Cover cars are provided for the bins to prevent weather conditions from changing the physical condition of the soil until a test can be completed. The cars, which also run on the bin rails, not only protect the soil from rain but retard drying by the sun.

The bins are provided with surface and subsurface drainage. The surface drainage, the cover cars, and the planting in the soil of crops, which serve to remove water from the soil, make it possible to produce the desired moisture condition in the soil.

Weather instruments are provided for the measurement of rain and other climatic variables. Recording equipment is provided for measuring surface and subsurface runoff.

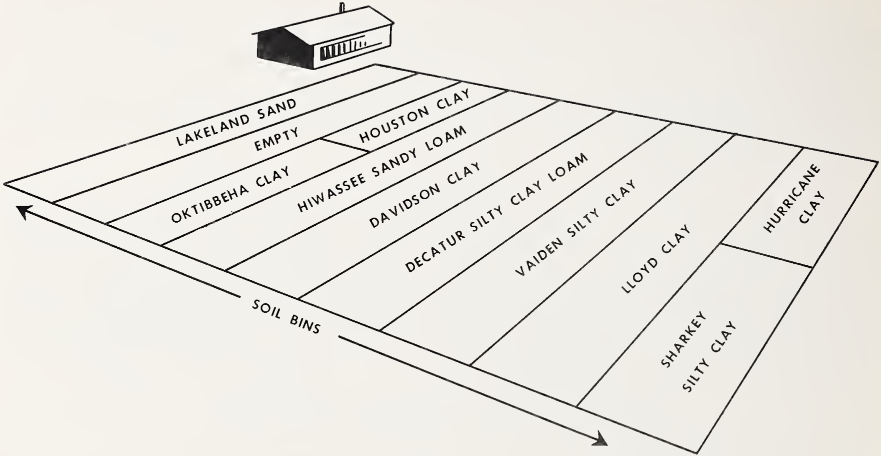
The Soils

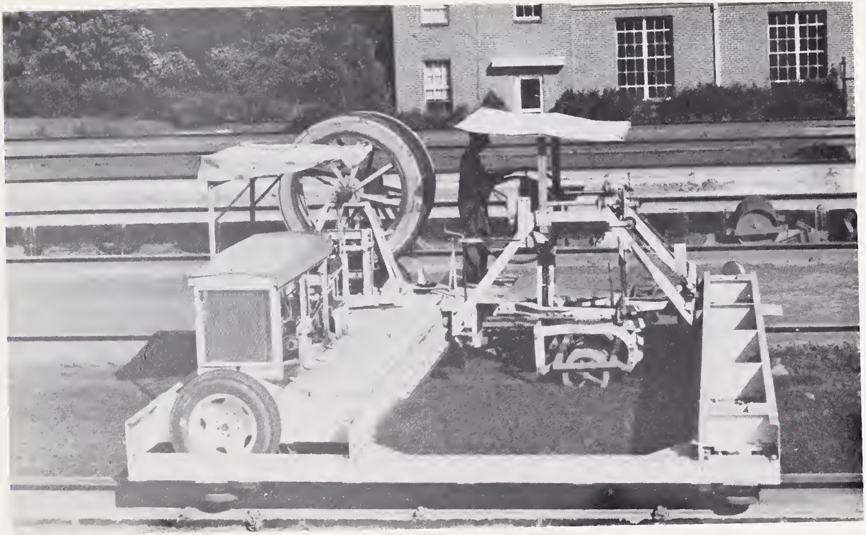
The soils in the bins were selected to give as broad a variation as possible in soil characteristics that affect the physical properties and tillage behavior of soils. They range from light sand to the heaviest colloidal clays, in both the highly weathered and the relatively unweathered soils. They are representative of most of the surface soils found in the Southeastern States. (For the mechanical analysis of the soils, see table 1. For the mineralogical analysis and organic matter content, see table 2.) The accompanying illustration shows the type of soils in the bins.

Equipment Used in the Bin Operations

Soil-Preparation Car

In order to obtain consistent results in a test, the soil must be uniformly prepared. The leveling, packing, or other operations necessary to put the soil in the desired condition are done with the soil-preparation car. This car is a self-propelled carriage which runs on the bin rails. Soil-working


LAKELAND SAND
EMPTY
HOUSTON CLAY
OKTIBBEHA CLAY
HIWASSEE SANDY LOAM
DAVIDSON CLAY
DECATUR SILTY CLAY LOAM
VAIDEN SILTY CLAY
LLOYD CLAY
HURRICANE CLAY
SHARKEY SILTY CLAY
SOIL BINS



The soil-preparation car.

tools--subsoiler, rotary tiller, disks, packers--are mounted on the car. The tool can be moved crosswise within the car frame in order to prepare any part or all of the soil in a bin. The tool can also be adjusted vertically in order to prepare the soil to a desired depth.

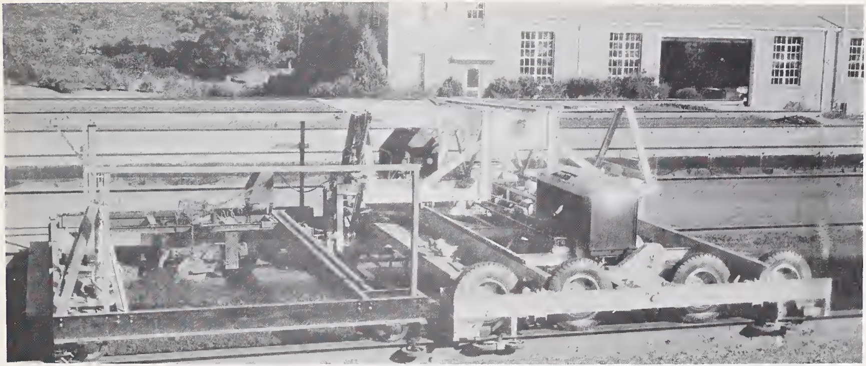
A sprinkler unit may also be mounted on the car. During the soil-preparation operations water can be applied to the soil to bring it up to the desired moisture content.

Power, or Dynamometer, Car

The power, or dynamometer, car furnishes the power for pulling the tillage tool during a test. It is a self-propelled carriage that runs on the bin rails, and to which a recording dynamometer is attached. Its speed ranges from 0.2 to 10 miles per hour.

The dynamometer is mounted in a superframe at the drawbar head of the car. The superframe can be moved crosswise in the car frame, and the dynamometer can be adjusted vertically in the superframe. The adjustments permit locating the hitch point of the dynamometer at any position relative to the tool being tested. The recorder makes a continuous record of the draft and the vertical and horizontal forces at the hitch point. The dynamometer will measure drawbar loads to 10,000 pounds.

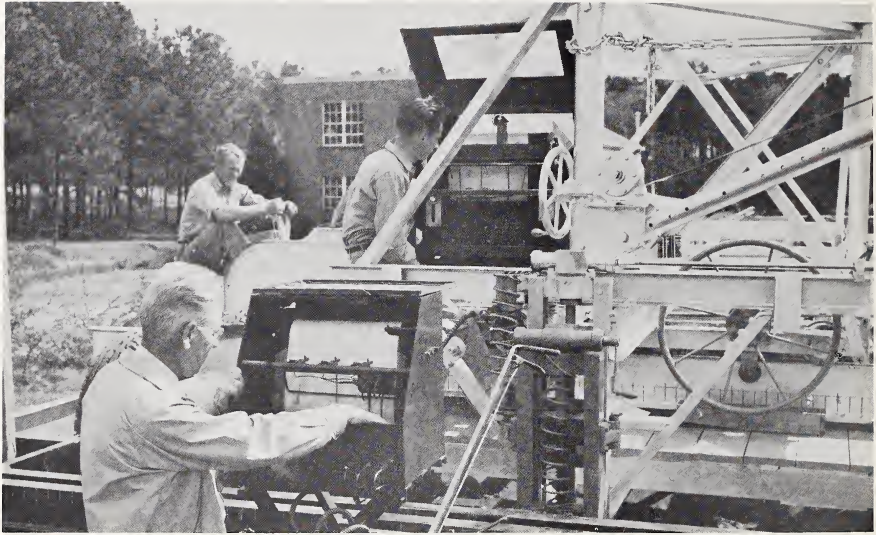
Traction equipment is also tested with this car. It may be used both as a load and for measuring drawbar pull.



The power, or dynamometer, car with the implement test car attached.

Implement Test Car

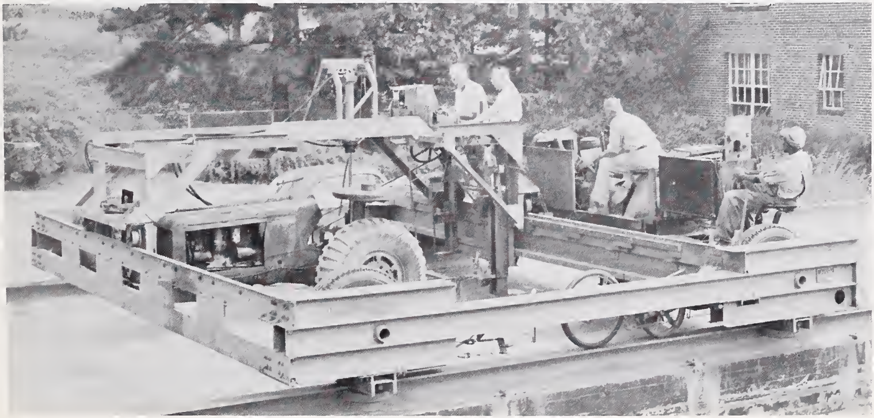
The implement test car carries the testing units on which the tillage tool is mounted. During a test, this car is hitched rigidly to the power, or dynamometer, car, so that the only load on the dynamometer is that required to pull the tillage implement in the soil. A recorder is also mounted on this car to record the horizontal and vertical reactions on the implement being tested.



The dynamometer car recorder (in the background) and the implement test car recorder.

Tire-Testing Machine

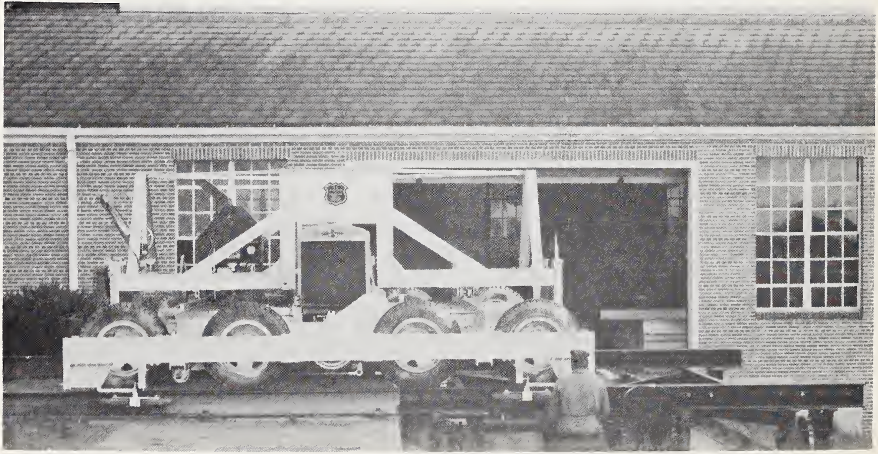
A special car is also in use at the laboratory for testing tires. This machine makes it possible to measure and record force input, drawbar pull, weight transfer, travel reduction, and inflation pressure changes for tractor tires operating in varying soil conditions.



The tire-testing machine.

Storage of Test Cars

When they are not in use, the various test cars are stored in an area in the laboratory building provided for that purpose. They are moved to and from the



The dolly car in operation.

bins by means of a dolly car. The dolly car is equipped with tracks that line up with the bin rails. It is also used to move cover cars and test cars from one bin to another.

The Soil Physics Laboratory

In addition to the tests made in the soil bins, research work is done in a soil physics laboratory. The purpose of the laboratory is to--

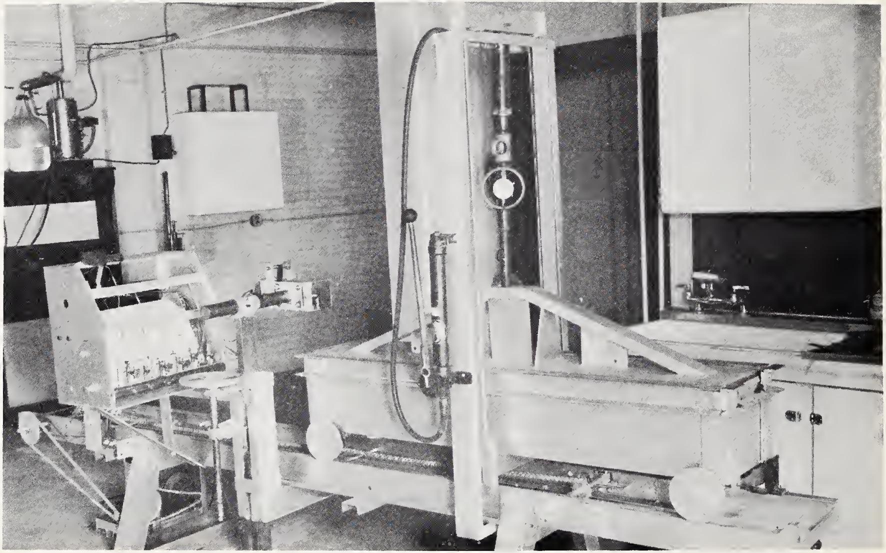
(1) Furnish information on the physical condition of the bin soils for guidance and control of bin operations.

(2) Provide facilities for basic research on the physical properties of soil to determine the relationship of measurable soil properties to equipment design.

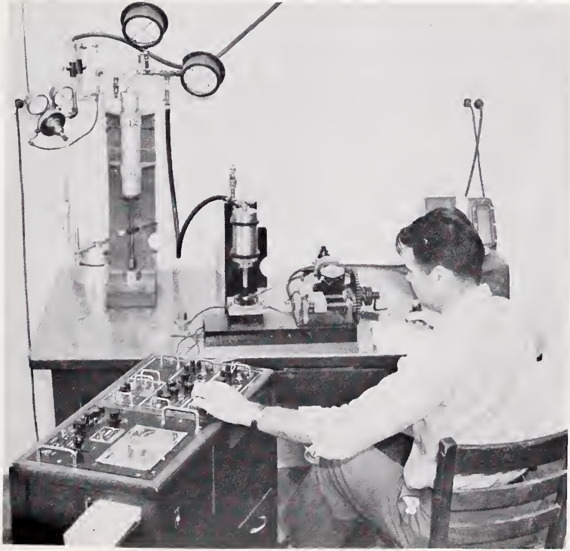
(3) Provide facilities for studying the effects of field equipment on soil characteristics that affect crop response. This research is done in cooperation with soil and plant scientists.

Much of the basic research work at the laboratory is done with model equipment. This saves the time and expense of constructing full-scale experimental equipment and avoids the labor required to prepare the soil bins. These model studies are made in the soil physics laboratory, which is equipped with a model soil bin and the necessary apparatus for making tests.

Equipment is also provided in the soil physics laboratory for making tests of soil samples taken from the bins. Measurements are made as to moisture content, state and degree of aggregation, structural stability, resistance to compression or bearing power, shear value, and the arch action or vectoring out of force through the soil mass.



Equipment in soil laboratory for making model studies.



A soil-testing machine in the soil physics laboratory

The Machine Shop

Shop facilities are provided for the construction of experimental equipment and the maintenance of the test cars and other equipment.

PUBLICATIONS

A list of technical publications resulting from the research work at the laboratory is available. The publications are an important contribution to scientific literature on tillage and traction equipment and related phases of soil science. In many cases, they report the results of cooperative studies with private industry, in which the cooperating companies have obtained data that helped them provide better service to the farmer.

Some of the publications are dated before 1935, when the laboratory was established. They report the results of research by agricultural engineers of the Alabama Agricultural Experiment Station. The results of this research led to a cooperative project with the United States Department of Agriculture which in turn influenced the establishment of the laboratory.

To obtain the list of publications, write to the--

Agricultural Engineering Research Division
Agricultural Research Service, U.S.D.A.
Plant Industry Station, Beltsville, Md.

Table 1. Mechanical Analysis of the Tillage Bin Soils

Soil Type Designation		Gravel Content > 2 mm. (%Total Soil)	Particle Size Distribution (% Organic Matter Free Soil < 2 mm.)							
Original	Present		Very Coarse Sand 2 - 1 mm.	Coarse Sand 1 - .5 mm.	Medium Sand .5 - .25mm.	Fine Sand .25 - .1mm.	Very Fine Sand .1 - .05mm.	Total Silt .05 - .002 mm.	Fine Silt .02 - .002 mm.	Clay <.002 mm.
Norfolk Sand	Lakeland Sand	0.1	2.0	29.0	25.3	29.6	4.7	7.3	5.5	2.1
Davidson Loamy Sand	Hiwassee Sandy Loam	0.1	2.0	19.5	23.3	25.4	2.9	10.9	8.3	16.0
Decatur Clay	Decatur Silty C. Loam	1.2	0.4	1.6	2.6	8.4	5.8	54.9	32.7	26.3
Davidson Clay	Davidson Clay	5.9	1.7	3.7	4.1	9.8	5.6	30.9	22.3	44.2
Cecil Clay	Lloyd Clay	1.5	2.2	4.3	3.7	7.4	5.6	17.2	11.2	59.6
Eutaw Clay	Vaiden Silty Clay	0.2	1.2	1.2	1.2	2.6	2.1	44.7	25.0	46.0
Sharkey Clay	Sharkey Silty Clay	0.0	0.2	0.2	0.2	0.4	0.6	41.2	35.0	57.2
Houston Clay	Houston Clay	0.6	0.4	0.4	0.5	2.0	1.8	32.4	21.1	62.5
Oktibbeha Clay	Oktibbeha Clay	0.3	0.6	1.3	1.0	4.3	13.4	18.3	6.8	61.1
Lufkin Clay	Hurricane Clay	0.1	0.1	0.6	1.0	2.1	1.7	28.1	19.8	66.4

Table 2. Organic Carbon Content, Reaction, and Mineralogical Analysis of the Tillage Bin Soils

Soil Type Designation		Clay Mineral Distribution - (% < .002 mm. clay)							Organic Carbon Content (% Soil < 2 mm.	pH
Original	Present	Iron (Fe_2O_3	Kao-linite	Mont-moril-lonite	Gibbsite	Quartz	Hydrous Mica	Unident-ified 14.3 A°		
Norfolk Sand	Lakeland Sand	11	15	--	10	40	--	20	.45	5.10
Davidson Loamy Sand	Hiwassee Sandy Loam	14	45	15	2	--	--	20	.87	5.32
Decatur Clay	Decatur Silty C. Loam	13	35	--	--	30	--	15	1.06	5.55
Davidson Clay	Davidson Clay	16	35	--	15	20	--	15	.84	5.11
Cecil Clay	Lloyd Clay	14	55	--	3	10	--	15	.78	5.15
Eutaw Clay	Vaiden Silty Clay	7	40	40	--	10	--	--	.93	4.51
Sharkey Clay	Sharkey Silty Clay	4	15	35	--	35	10	--	.78	5.42
Houston Clay	Houston Clay	5	25	50	--	10	--	--	1.30	7.46
Oktibbeha Clay	Oktibbeha Clay	11	35	35	--	5	--	--	1.21	4.62
Lufkin Clay	Hurricane Clay	4	15	45	--	35	--	--	1.73	4.61